

Assessing Levels of Airborne Bioallergens in New York City

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Sampling of airborne ragweed and other pollen grains in the City of New York is described as it took place during the months of August and September 1973. Three sampling stations participated in the program. This effort was meant to serve as the forerunner of a citywide volunteer pollen sampling network based on the cooperation of existing health care providing institutions, schools, and stations of the operational sampling network of the New York City Department of Air Resources. Monitoring stations were set up on the roof of Cooper Union School of Engineering at 51 Astor Place in downtown Manhattan, at the Boyce Thompson Institute for Plant Research, Inc. at Yonkers, N.Y. and use was made of the data supplied by Middlesex General Hospital, New Brunswick, N.J.

Seasonal results of ragweed pollen sampling, undertaken at the downtown New York City location of Cooper Union with the swing-shield intermittent rotoslide sampler, are similar to those of studies undertaken in the 1940's and 1950's with the Durham slide sampler in the New York metropolitan area. Comparison of the collected data with converted data obtained in 1979 at Long Island Jewish-Hillside Medical Center with the aid of a Durham gravity slide sampler shows the trend similarity of the data collected by us in 1973 and those obtained in 1979.

Collected data of the 1973 ragweed season were supplied to the New York City news media on a daily basis, as a much appreciated service to the public.

Bioallergens are part and parcel of the perennially present aero-allergens, especially in a city like New York where a large number of citizens suffer through the various pollen and mold seasons year after year. The ever increasing number of querying phone calls to the Bureau of Science and Technology of the New York City Department of Environmental Protection induced the authors to investigate this problem together with local institutions who volunteered their assistance. Pollen grain and mold pore sampling stations could provide a local inventory of airborne allergens, and an indication of their dispersal throughout the metropolitan area. In conjunction with weather data, this may allow the development of a predictive model for airborne allergen levels. Such a monitoring system in combination with a prognostic capacity would potentially be beneficial to the health of the population of the City of New York.

Hay fever may seem rather innocuous. However, when asthma develops as a sequela, which may occur in a large portion of the population suffering from hay fever, mortality may increase appreciably (1,2). Hence, a number of sampling methods were assessed in order to select the most suitable and accurate instrument to serve as a basis for a dependable sampling network: For many years, the Durham or gravity slide sampler has been in use during the ragweed pollination season for monitoring airborne pollen levels, as recommended by the Pollen and Mold Committee of the American Academy of Allergy. Counts were usually taken over a 24-hr period and reported as grains per square centimeter. However, these counts are not necessarily representative due to the influence of atmospheric turbulence and wind speed on slide deposition. Also, the orientation of the slide with respect to the wind direction greatly influences the number of pollen grains trapped. Furthermore, it is impossible to determine the volume of air sampled in the field. Hence, a number of more quantifying sampling methods were investigated. As the most convenient and representative mode of monitoring levels of airborne bioallergens, the swing-shield

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intermittent roto-slide sampler (3-5) was selected. This monitor, its action, the handling of the samples it takes, and the conversion of pollen counts, obtained from the roto-slide sampler, to volumetric measurements, assuming the efficiency of the sticky slide edge surface to be 64% for airborne ragweed pollen, have been described fully (4). The efficiency is determined from a measurement of estimate of mean wind speed during the sampling period, and varies linearly from 68% at zero speed to 49% at 10 mps for ragweed pollen. Volume monitored is determined from length of sampling period, and a constant which includes the cross sectional area of the slide-edge sampling surface, the linear travel per revolution and rate of rotation. The normalized pollen count is divided by the volume and efficiency to determine concentration of pollen grains per cubic meter of air.

In New York City and surrounding regions (6), three pollen seasons can be distinguished, that of early spring, early summer, and of late summer. The earliest pollinators are elms, maples, and willows in April. Clinically more important are the poplars and birches which shed their pollens in late April and the first two or three weeks in May. Oaks, ashes, and beeches also pollinate in May, hickory a little later. Grass pollen concentrations, though not as high as those produced by trees, affect more people, with often more severe symptoms, in the early summer approximately until early July. Nonetheless, we have found grass pollens through September. Pollen of the weed English plantain can be found from May through August. The prime offender of pollinosis, however, is ragweed pollen, which pollutes the New York City air in bothersome quantities from approximately mid-August to the end of September.

The various pollens and molds not only show seasonal patterns but also pronounced diurnal emission cycles can be observed. Each genus has its own characteristic diurnal emission pattern (7). Ragweed pollen emission usually begins near sunrise, peaks a few hours later, and decreases through the afternoon. The peak count most frequently is between 9 and 10 AM. Periods of maximum airborne pollen concentrations are directly related to maximum atmospheric turbulence. The process of pollen release takes place in two stages: (1) release from the anthers is determined by time of day, temperature and relative humidity; and (2) the actual transfer of the pollen grains from leaf surfaces to the air takes place by turbulence and windspeed. These processes are as follows: Stable atmospheric conditions usually prevail in the early morning hours before sunrise and are associated with a low-level temperature inversion, which means

very low surface wind speeds with complete absence of turbulence with isothermal to adiabatic lapse rate conditions. As the sun rises higher and heats the surface, unstable conditions develop, accompanied by superadiabatic lapse rates which promote turbulence. This facilitates pollen transport from the plant leaves to the air. Emission most typically begins when stable, moist night time conditions give way to unstable and drier air shortly after sunrise (7). Vertical pollen profiles show great variability from day to day because of varying weather conditions.

In this respect, the efficiency of the intermittent roto-slide sampler, used in our three-station network, is independent of wind direction and windspeed. Raynor, Ogden, and Hayes (8) sampled ragweed pollen concentrations at heights of 1.5, 11.3, 22.8, 45.7, and 108.2 m, respectively, with the intermittent roto-slide sampler. They found that the upper level was the most representative of regional concentrations and the least influenced by local turbulent conditions. Actual ragweed pollen grain concentrations did not differ much with the presence or absence of nearby local sources. The authors concluded that "the diversity in size, distance, and location of ragweed sources, and in timing, duration, and magnitude of pollen emission, plus the variability in meteorological conditions between source and sampling locations, form such a complex set of possible variables that variation with height over short periods cannot be related to parameters measurable at the sampling site. However, when averaged over longer periods of time, these variables tend to counteract each other so that a smoothed profile results."

Sampling Methods

In view of the above, we decided to launch a city-wide network of pollen and mold sampling stations equipped with the intermittent swing-shield roto-slide sampler developed by Raynor and Ogden (3-5). Two instruments were purchased commercially while an antiquated model with circular shield in the laboratory of the Bureau of Science and Technology was transformed by laboratory technicians into an intermittent swing-shield roto-slide sampler (Fig. 1). This instrument was installed on the roof of Cooper Union School of Engineering at 51 Astor Place in downtown Manhattan. Sampling for the ragweed season began on August 6, 1973 and was terminated on September 26, 1973. The instrument was timed to sample intermittently for 1 min every 12 min from 6 to 10 AM every day, except on weekends, as usually pollen counts rise

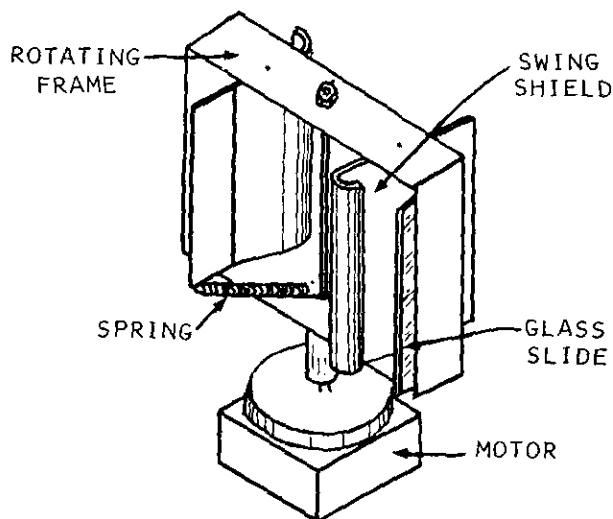


FIGURE 1. Swing-shield intermittent rotoslide sampler (1-5). Drawing graciously supplied by Center Laboratories, Port Washington, N.Y.

sharply during early to mid-morning, and decrease rapidly thereafter.

In the months previous to the beginning of the ragweed season, the Boyce Thompson Institute for Plant Research, Inc. at Yonkers, N.Y., was approached and found willing to have one of our rotoslide samplers installed on its property, and analyze exposed slides on a daily basis.

Middlesex General Hospital in New Brunswick, N.J., had been supplying ragweed pollen data to the New York City news media for the past several years. As these data were derived from a rotoslide sampler identical to the ones installed at Cooper Union and Boyce Thompson, we contacted the hospital to obtain its daily count. Our request was acceded to graciously. This permission resulted in a miniature ragweed pollen sampling network of three stations.

In the meantime, we had received a dozen rotoslide samplers and six sampling heads from the New York State Government, in Albany, N.Y. While these were readied to be installed in a city wide network of sampling stations, a preliminary three-station network consisting of the above locations was ready to operate at the beginning of the 1973 ragweed pollen season. The Cooper Union location represents the central area on the receiving end of the pollen grains. Middlesex Hospital data in general gave an indication of ragweed pollen levels to which the Borough of Manhattan would be exposed. New Brunswick, N.J., is situated southwest of New York City where the most offending pollen pollution occurs during a weather pattern in

which a southwesterly to westerly wind prevails. Northwesterly winds affect the Bronx directly; hence, the Boyce Thompson sampler would be indicative of ragweed pollen levels in that Borough. At Boyce Thompson Institute for Plant Research of Yonkers, N.Y., the rotoslide sampler was set up at a level of about two meters above the ground while at Cooper Union, in the southern part of Manhattan, and at Middlesex General Hospital in New Brunswick, N.J., identical samplers were set up on the roof of their respective buildings at a height of approximately 30 m above street level. This height difference does not seem to result in significantly different sampling results (8).

Sampling for the 1973 ragweed season was started on August 6th and terminated on September 26th of that year. Only ragweed pollen counts were reported to the New York City news media on a daily basis, although at the Bureau of Science & Technology as well as at Boyce Thompson slide edges were analyzed for other pollen grains and mold spores. Table 1 shows the daily ragweed pollen counts at the Cooper Union, Boyce Thompson and Middlesex General Hospital stations, together with morning surface wind direction and morning average wind speed in the mixing layer as measured at Fort Totten, N.Y. Corresponding weather observations at the U.S. Weather Bureau's Central Park Observatory in Manhattan also were analyzed. It was found that weather data at the park could not always explain the collected sampling data, most probably due to the fact that Central Park is located within a large heat island with a varied topography due to an agglomeration of high rise buildings, and due to the prevailing sea and land breeze system superimposed on the local meteorological conditions.

Table 1 clearly shows a number of peaks in the daily ragweed pollen count which will be discussed. On August 10, the wind was southwesterly, i.e., from areas which are source regions of pollens and mold spores for New York City, which at the time was located in the warm zone of a frontal system. The same situation prevailed the following day. As indicated, the cold front passed the area between August 12 and 13, when the wind veered to NW. However, the area northwest of New York City also serves as a source region for pollen grains. Hence, the mildly higher sampling result of 18 pollen grains/m³ of air sampled in the city and 17/m³ at Boyce Thompson. On August 16, rain in the early morning hours cleansed the atmosphere. Hence, the pollen count was zero. The probable reason for the Boyce Thompson count of 4/m³ is that the institute is surrounded by suburban and rural areas which serve as nearby source regions, while the

rain stayed south of the station. On August 22, a similar situation developed, only now precipitation also occurred at the Boyce Thompson site. The last days of August show a large increase in pollen sampling counts, peaking August 28 at the three ragweed pollen sampling stations. During this period, the Bermuda High extended over the eastern half of the continental U.S., thereby creating a steady southwesterly atmospheric flow which transported the large amount of pollens from the source

regions to the New York City metropolitan area. Subsequently, the high pressure area retreated. Early September a similar situation developed.

On September 6 and 7, the pollen count peaked at Boyce Thompson and Cooper Union respectively. From this occurrence on, counts diminished steadily towards fall with two minor peaks occurring on September 14 and 20. In general, pollen counts increase in the warm sector of a weather disturbance, when southwesterly winds sweep pollens

Table 1. Ragweed pollen counts sampled on weekdays at Cooper Union, Boyce Thompson Institute and Middlesex Hospital with a swing-shield intermittent rotoslide sampler from August 6, 1973 through September 26, 1973.

Date 1973	Number of pollen grains/m ³			AM surface wind direction at Fort Totten, N.Y. ^a	AM average wind speed in mixing layer m/sec ^d at Fort Totten N.Y.	Observations
	Cooper Union	Boyce Thompson	Middlesex Hospital			
8/6	3	~	~	N	2.5	
7	13	0	~	SW	2.3	
8	6	6	~	SW	4.3	
9	11	2	~	SW	6.8	
10	13	13	~	SW	5.2	In warm zone of frontal system
13	18	17	~	NW ^b	4.5	
14	3	1	~	NE	4.0	
15	6	4	~	NE	4.6	
16	0	4	~	NE	5.2	Precipitation in early morning hours
17	10	6	~	Variable	2.1	Wind NE on 8/18 and 8/19
20	6	23	14	NE	2.2	
21	7	89	12	NE	7.3	
22	0	0	12	NNE	7.6	Precipitation in early morning hours
23	17	45	30	N	4.9	
24	72	21	92	NE	5.0	
27	231	158	77	SW ^c	3.5	Large extension of Bermuda High over eastern half of continental U.S.
28	403	208	256	WSW	6.5	
29	147	150	252	WSW	2.0	
30	306	168	140	WNW	3.5	
31	75	120	133	Variable	3.0	
9/4	112	31	36	Variable ^d	1.5	
5	123	31	31	SW	3.0	High retreating eastward
6	157	147	97	SSW	6.0	In warm zone of frontal system
7	274	97	63	WNW	4.4	Cold frontal passage
10	0	23	31	NNW	4.0	During weekend wind direction remained WNW and W
11	20	53	24	WSW	8.8	
12	31	31	22	NW	9.3	Cold frontal passage between 7 AM 9/11 & 7 AM 9/12
13	26	12	14	SW	1.8	
14	72	52	18	ESE	7.3	
17	23	22	10	NE ^e	6.0	
18	10	4	6	S	5.5	Approaching area of low pressure
19	4	7	8	N	7.7	cold front passed
20	59	17	4	SW	5.5	In warm sector of frontal system
21	14	8	~	NE	6.0	
24	6	6	~	NE ^f	4.5	
25	11	7	~	NE	7.4	
26	3	0	~	ENE	3.5	

^aData obtained via Bureau of Science & Technology of New York City Department of Environmental Protection, Division of Air Resources.

^bWind veered with passage of cold front between 7 AM 8/12 and 7 AM 8/13

^cWind veered from NE to SE with High moving in easterly direction between 7 AM 8/24 and 7 AM 8/25, and hence to SW.

^dDuring Labor day weekend, wind direction was SW on 9/1 then was NE on 9/2 and variable on 9/3.

^eLow pressure area to south of New York City moved eastward from 9/14 to 9/15 bringing rain to area on 9/16 NYC again in warm sector of following frontal system, with SW wind. Cold frontal passage brings NE wind on 9/17.

^fWind veered to SE with approaching frontal system on 9/22, then to SW on 9/23 after which a cold front passed.

and mold spores towards the metropolitan area. Winds from southwest to west-northwesterly direction usually bring great quantities of allergens to New York City. Frontal or local convection rainstorms completely clear the atmosphere by their scavenging action. Simultaneously with analyzing for ragweed pollen presence at Cooper Union, slide edges were scanned for the presence of grass and English plantain pollens, and for *Alternaria*, *Helminthosporium* and *Hormodendrum* mold spores. Table 2 gives the corresponding daily counts. High counts of pollen grains and mold spores coincide with those of ragweed pollens as is shown graphically in Figure 2. This fact indicates

that the pollen and mold source regions for the sampling stations, whose counts are reported here, are located in areas to the southwest to west-northwest upwind. In the course of this study, an endeavor was made to correlate sampling results with weather parameters. A steady relationship could not be established. It was found that wind direction and average speed in the atmospheric mixing layer gave the best indication of the level of pollen and mold spore counts. Analysis of height of the mixing layer showed that this parameter does not seem to have a significant influence on the counts registered.

In order to show that the ragweed pollen data

Table 2. Counts of grasses and English plantain pollen grains and of *Alternaria*, *Helminthosporium*, and *Hormodendrum* spores as observed at the Cooper Union Laboratory of the New York City Department of Environmental Protection, Division of Air Resources from August 6 through September 26, 1973, using an intermittent rotoslide sampler operated from 6 to 10 AM each weekday morning.

Date 1973	No. of pollen grains/m ³ of air ^a		No. of mold spores/m ³ of air ^a		
	Grasses	English plantain	<i>Alternaria</i>	<i>Helminthosporium</i>	<i>Hormodendrum</i>
8/6	4	1	16	0	Low
8/7	9	0	30	1	Low
8/8	8	1	8	1	Low
8/9	6	4	21	4	Low
8/10	5	0	22	8	Low
8/13	NC	NC	NC	NC	NC
8/14	NC	NC	NC	NC	NC
8/15	3	0	4	1	Low
8/16	0	0	3	0	Low
8/17	0	0	13	2	Low
8/20	8	1	10	3	Low
8/21	7	3	0	1	Low
8/22	3	0	0	0	Low
8/23	2	0	0	0	Low
8/24	30	30	15	0	Medium
8/27	9	0	17	4	High
8/28	10	10	27	2	High
8/29	14	6	65	22	High
8/30	44	0	182	16	High
8/31	4	0	38	0	High
9/4	21	17	35	17	High
9/5	15	0	29	2	High
9/6	14	6	11	0	Medium
9/7	73	0	152	21	High
9/10	NC	NC	NC	NC	NC
9/11	NC	NC	NC	NC	NC
9/12	NC	NC	NC	NC	NC
9/13	NC	NC	NC	NC	NC
9/14	NC	NC	NC	NC	NC
9/17	6	0	0	0	Low
9/18	3	1	3	0	Low
9/19	0	1	0	0	Low
9/20	7	13	41	1	Low
9/21	0	3	1	0	Low
9/24	3	6	1	0	Low
9/25	3	1	0	0	Low
9/26	2	2	2	0	Low

^aNC = not counted.

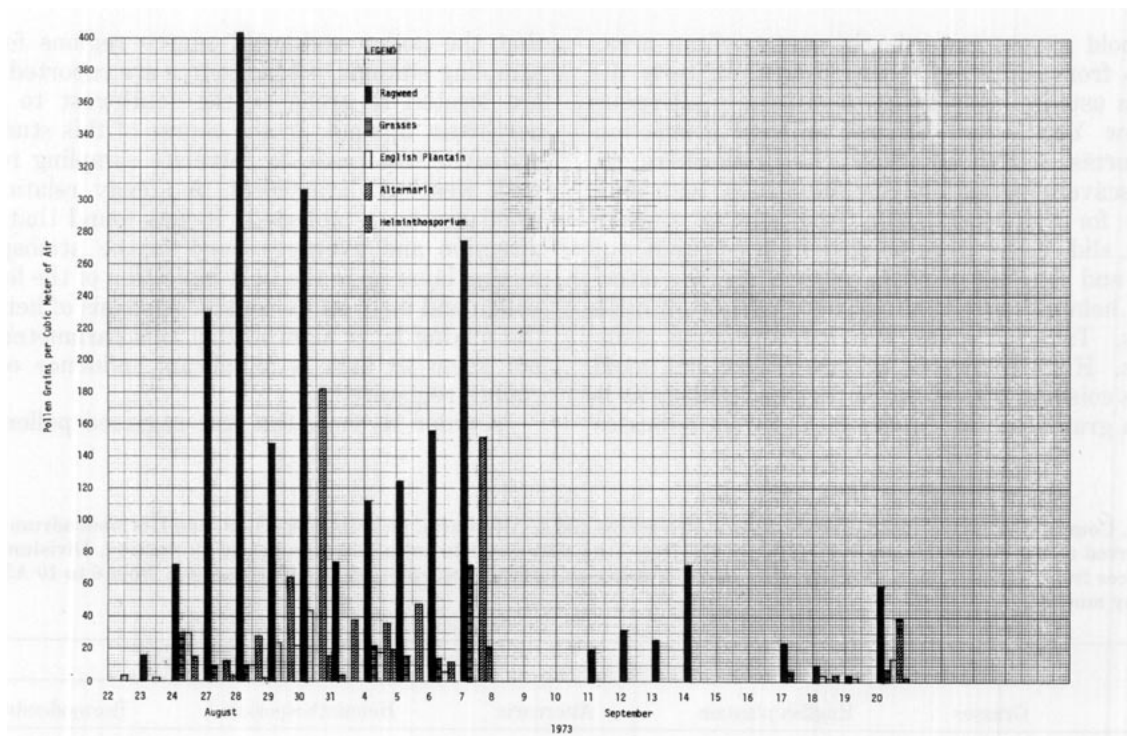


FIGURE 2. Number of pollen grains per cubic meter of air sampled at Cooper Union with intermittent swing-shield rotoslide sampler in 1973.

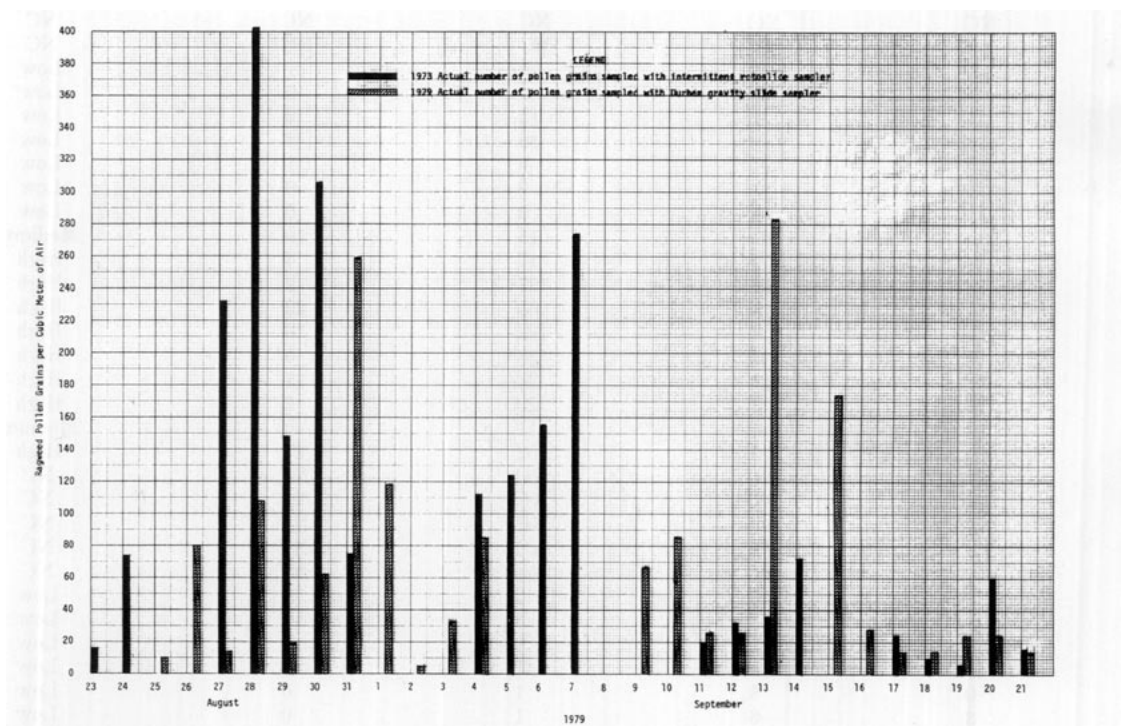


FIGURE 3. Comparison of number of ragweed pollen grains per cubic meter of air sampled at Cooper Union with an intermittent swing-shield rotoslide sampler in 1973, and number of ragweed pollen grains per cubic meter of air sampled at Long Island Jewish-Hillside Medical Center with a Durham gravity slide sampler in 1979.

collected in 1973 with an intermittent roto-slide sampler are still representative for the 1979 season, these have been plotted in Figure 3, which also shows the results of seasonal sampling with the aid of a Durham gravity slide sampler, obtained in 1979 at Long Island Jewish-Hillside Medical Center. These counts are lower than those collected with the roto-slide sampler. In this respect, Durham (9) estimated, by means of parallel volumetric measurements, that with his sampling device the amount of ragweed pollen grains, deposited on 3.6 cm^2 of the microscope slide surfaces ($2 \times 1.8 \text{ cm}^2$), is approximately equivalent to the numbers of grains per cubic yard of air. Hence, we converted the 1979 data, expressed in grains per square centimeter of slide surface, to numbers per cubic yard by multiplying them by 3.6. In turn, we adjusted the results to the number of ragweed pollen grains per cubic meter of air in order to make the data comparable with our 1973 data.

Discussion

At this point, it is useful to elaborate on the process of pollen dispersal from the ragweed flower as described by Holmes and Bassett (10) thereby quoting Bianchi et al. (11). The latter showed that the stage of dehiscence of the ragweed flower is a function of temperature, that is the preparation for the process of dehiscence. After that, the process is a function of vapor pressure in the microclimate of the plant. Flowers will not disgorge pollen until the vapor pressure reaches the threshold which permits the anther envelop to desiccate to the point where it ruptures and allows the pollen to be spilled out. Dehiscence, therefore, is a function of temperature and vapor pressure. There are three steps before actual pollen dispersion takes place: ejection from the flower, adherence of pollens to adjacent vegetation, and flotation caused by turbulent air. The latter only takes place under conditions of a superadiabatic lapse rate in the microclimate of the plant cover, when the relative humidity sharply decreases. The period of maximum pollen concentration varies widely but occurs in the morning hours, except during precipitation. These observations mean that in order to predict possible pollen concentrations at areas of deposition, two sets of atmospheric data have to be procured: micrometeorological lapse rate, temperature, and humidity in the source region and synoptic meteorological data in the area of deposition. The air cleaning action of precipitation in both areas is self-evident, so that the forecast of precipitation is of the utmost importance. In order to establish local mean seasonal curves of pollen concentration, Raynor and

Hayes (12) recommend that several years of quantitative ragweed pollen concentration measurements be obtained for sites of interest. Consideration should be given to type of air mass, length of time this air mass has lingered over pollen-producing regions, frontal passages, air trajectory, wind direction and speed, as well as amount of sunshine, turbulence, especially superadiabatic lapse rates early in the morning in the lower boundary layer at the source. Periods of maximum airborne pollen concentration seem to be related to periods of maximum air turbulence in the boundary layer which together with increasing wind elevates the pollen count sharply. Hence, it should be realized that forecasting the pollen levels at destination is a very complicated matter in which a variety of meteorological and micrometeorological parameters should be available before attempting an indicative correlation. Also, the amount of precipitation in the source region should be considered in the months that the ragweed plant develops, as well as the amount of sunshine in the days that the plants reach maturity and release their pollen.

When comparing the results of the ragweed pollen grain data collected with the roto-slide sampler in 1973 and with the Durham sampler in 1979, it should be realized that the instruments operate on completely different principles. Using the factor of 3.6 to equate sampling results of both instruments is wholly empirical. The only advantage is that trends in the data may be compared. Figure 3 shows that although on some days data are missing, a general trend can be distinguished. Trends registered in 1973 and in 1979 are slightly out of phase, but still cover the same season. The being out of phase of the data may well be due to the fact that in 1973 and in 1979 sampling locations are different geographically by a distance of approximately 10 miles, although still within the confines of New York City. Similar geographical differences in peak occurrence of ragweed pollen grains are mentioned by Wiseman et al. (13). Hence, the authors feel that the 1973 ragweed pollen data are still representative of presently existing conditions.

Conclusion

Sampling for the presence of airborne pollens and mold spores was undertaken in the New York City Metropolitan area. Simultaneously, U.S. Weather Service data for Fort Totten, N.Y. and Central Park Observatory were analyzed. This study would be needed for a number of years, from March through October, to establish yearly curves for the presence of the various types of allergens in the metropolitan area. Micro- and macroclimatological

data for the source regions and area of deposition respectively and epidemiological data in the receiving area would complement the gathered bioallergenic data to establish patterns which could be used as a tool in the forecast of airborne allergens over New York City. This information would not only enable allergic patients better to protect themselves against the expected cityward flow of allergens, but it also would be of value to consulted physicians in correlating symptoms with the presence of certain pollen grains and mold spores. The reported investigation was undertaken as a beginning of the planned program. Sampling results of the 1973 ragweed pollen season were supplied to the news media on a daily basis (weekdays only) as an important service to the public.

Ragweed pollen sampling data collected in 1973 and in 1979, although obtained with different samplers and at different geographic locations within New York City, still show a similar trend qualitatively within the same time span. Hence, we submit that the results of our sampling program in 1973 represent presently existing airborne pollen grain conditions in New York City.

The research described in the paper was done under the auspices of the Department of Environmental Protection, City of New York.

Mr. Gilbert S. Raynor, meteorologist at the Brookhaven National Laboratory, Upton, N.Y., supplied us with literature with respect to pollen sampling, acquainted us with methods of sampling and analysis, and advised us how to proceed.

Ely Perlman, M.D. supplied the 1979 ragweed season data taken at Long Island Jewish-Hillside Medical Center with a Durham gravity slide sampler.

Mr. Walter Jinotti, technician at Middlesex General Hospital, New Brunswick, N.J. was most helpful in sharing with us his experience in methods of pollen analysis, use of the intermittent

swing-shield roto-slide sampler, and supplying us with his sampling data.

Dr. Jay Jacobson of the Boyce Thompson Institute for Plant Research, Inc., Yonkers, N.Y. had one of our intermittent swing-shield roto-slide samplers installed at the Institute, and supplied us with daily sampling results.

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